Michael Goetz

Multi-angle Imaging SpectroRadiometer

Jet Propulsion Laboratory

"Quantification of Asian Dust Plume Seasonal Dynamics and Regional Features"

3 March 2011

This Cooperative Education Report has been submitted to Olga Kalashnikova and has been approved for release and submission to Dr. Francis X. Flores, Cooperative Education Director, Cal Poly, Pomona during the 9th week of the quarter.

Signature:____________________________ Date:_____________________________

Acknowledgement:

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, and was sponsored by the Research Apprenticeship Program and the National Aeronautics and Space Administration.

Table of Contents

B. Objectives

The objectives were to determine the distribution of dust plumes within the Taklamakan Desert, study the behavior of dust within the region to see where dust is being transported, and compare this region to other dust regions around the world.

C. Executive Summary

Dust is but one of many aerosols that are analyzed at the Jet Propulsion Laboratory in Pasadena. The purpose of this paper is to describe the process in analyzing and digitizing dust within a source region to better explain the work achieved by my internship. This paper will go over how to view collected data by Multi-angle Imaging SpectroRadiometer (MISR) [1] and the procedure of downloading data to be analyzed. With this data, one can digitize dust plumes using two methods called plume lines and plume polygons with the help of the software MISR INteractive eXplorer (MINX)[3]; thus, the theory of MINX's[3] algorithm and these methods are discussed in detail. Research was gathered from these techniques and emphasis is also focused on the obtained data and results.

D. Description of Position and Activities

Before the events of World War II, a group of students from Caltech decided to turn what was perceived as science fiction into a reality. With their knowledge of aerodynamics, mechanics, and chemistry; nevertheless, following the works of Robert Goddard they tested and launched small scale rockets in an area near the San Gabriel Mountains. This was the beginning of events to come that created one of the prestigious research facility in the world know as JPL. Even though JPL was first founded based on the development of rocketry, it has grown to encompass numerous divisions that branch into Business, Engineering, and Science.

I worked in the Earth and Atmospheric Science department in division 3285, Cloud and Aerosol, and was mentored by Olga Kalashnikova. Olga Kalashnikova works with the MISR[1] team at JPL. She is an aerosol scientist and is knowledgeable in optical properties of mineral dust. With her knowledge, she had created aerosol models for remote sensing application and uses satellite data for climate analysis. This was all achieved with her various educational credentials. She has received her Bachelor's and Master of Science Degrees in Physics at Kazakh State National University, Kazakhstan. She continued her education here in the states with a Masters in Physics and PhD in Atmospheric Sciences at the University of Colorado at Boulder. This has lead to numerous publications such as "Mineral dust plume evolution over the Atlantic from MISR and MODIS aerosol retrievals" and "Importance of shapes and compositions of wind-blown dust particles for remote sensing at solar wavelengths".

The MISR[1] team that Olga works with has many goals and objectives. One objective is to better understand the effects of aerosols on the climate. Aerosols are tiny particles in the air that can be created naturally such as water particles in clouds and ash from volcanoes; however, aerosols also include manmade particles such as pollution from fossil fuels. Another aerosol that the MISR[1] team studies is dust and its effects on the planet. These include effects on climate, human health, and various ecosystems. Previous works done on the study of dust regions include the ten year analysis on Saharan dust and its behavior transportation across the Atlantic Ocean. My position is to analyze the behavior of dust within the Taklamakan Desert to create better climatology model and determine where dust is being transported within the region. A ten years collection of data obtained by MISR[1] is available to the public and with this data, I was able to process and analyze trends and conditions that create dust activity. All of my time was spent in distinguishing and collecting MISR[1] data and digitizing the data to determine the plume heights and wind speed of individual dust plumes within the Taklamakan Desert.

E. Descriptions of Project Completed and Data

E.1: Data Collection

MISR[1] is in a polar sun-synchronous orbit around the Earth. This scientific instrument has nine individual cameras that point at different angles in relation to the Earth. These angles are pointed in a way to be beneficial in determining the heights of clouds and terrain, analyzing thermal radiation, and scanning aerosols by looking through maximum atmospheric area. The nine cameras can also see in four color bands: red, green, blue, and near infrared. These wavelengths help determine the location of vegetation, reflective properties, and size and distribution of aerosol particles. As MISR[1] goes from pole to pole is uses its nine cameras to scan and take data of the land. The first step in analyzing orbital data collected by MISR[1] is to go through the public accessible database. All the data could be found on MISR's home page (http://www-misr.jpl.nasa.gov/) under the *Get Data* tab. Within this section one could navigate to the *Browse Tool* that is displayed in Figure 1.

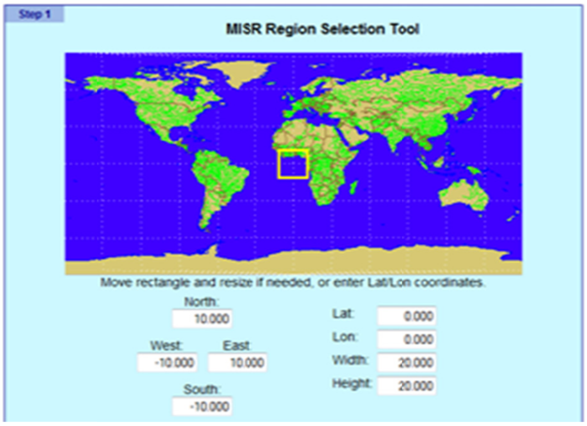


Figure 1: Browse tool to view MISR data.

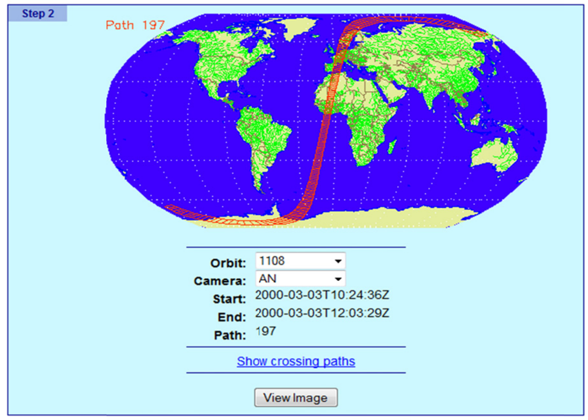


Figure 2: Display of orbital path over region with drop down menus to access different orbits and cameras.

There are a variety of options to select in obtaining data. The common method used is inputting the latitude and longitude coordinates to move the yellow box over the desired region. Upon completion, a second window will appear which displays the path number[2], orbit number, camera, and time the data was collected. This can be shown in Figure 2. Depending on how big the region is, multiple orbits that go over the region are also obtained and can be accessed in the pull down *Orbit* menu in Figure 2. The camera can also be changed to the other 8 cameras that MISR[1] uses to take data over the region. Once the desired orbit and camera is selected, the selection of *View Image* is used to obtain a low resolution image of the orbit over the desired region. An example of this image is shown in Figure 3.

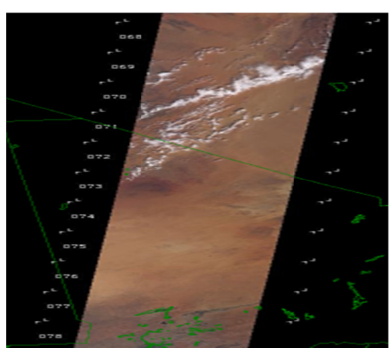


Figure 3: Display of Low Resolution Orbital Image of Desired Region

From the low resolution image, the presence of dust within the region can be determined.

E.2: Data Ordering

Data collected by all nine cameras are stored at NASA Langley Atmospheric Science Data Center. The server can be accessed through the internet and Figure 4 shows the user interface of the website. Selecting *Aerosols* refines the data products to only aerosol data and the four associated files needed are highlighted in blue in Figure 4.

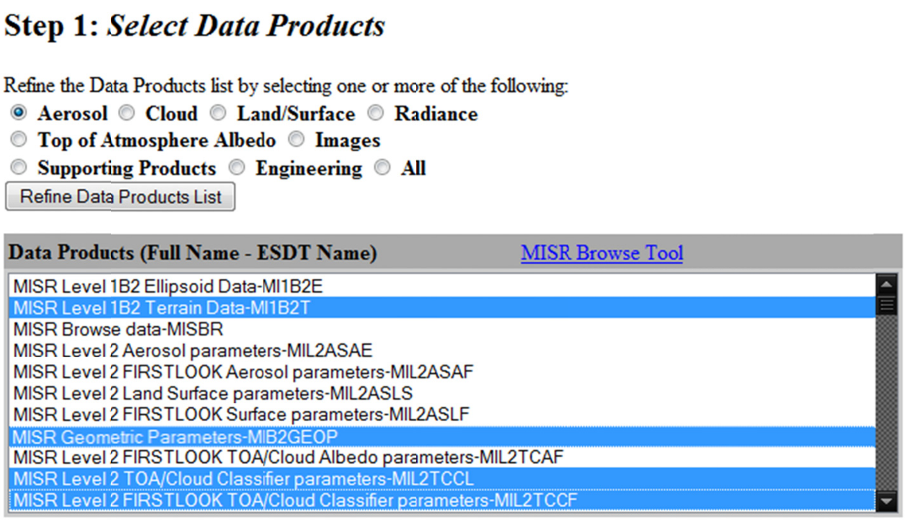


Figure 4: NASA Langley Atmospheric Science Data Center Order Tool

The next step is to specify the orbit number the data comes from. This is done under *Temporal Search* which is demonstrated in Figure 5. This action allows one to only select data that is collected from that orbit. In addition, all nine cameras need to be selected.

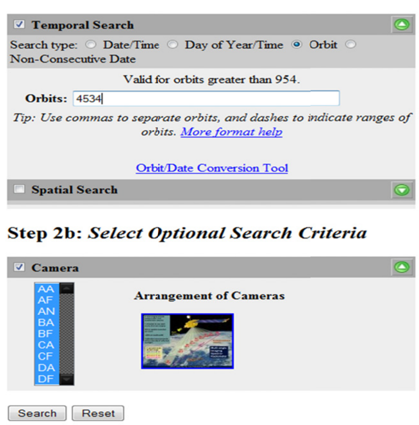


Figure 5: Demonstration of selecting an orbit and all nine cameras.

Upon completion one can proceed with checkout and the submission of their order.

E.3: Uploading Files into the Software

Before one can begin digitizing the obtained data, the data needs to be uploaded into the software. The software used is MINX[3]. To upload the obtained data from MISR[1] one should open up MINX[3]. Once open, *Animate Cameras* needs to be selected. The reason for selecting this option is interlay the nine downloaded camera files on top of each other to create a flipbook effect that shows the movement of dust plumes within the region. Once *Animate Cameras* is selected, the user should see an interface like the one shown in Figure 6

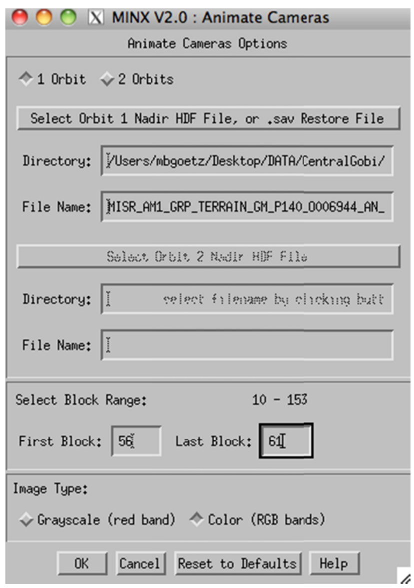


Figure 6: User Interface within MINX[3]. Demonstrates how to upload files and select the correct block number upon digitization.

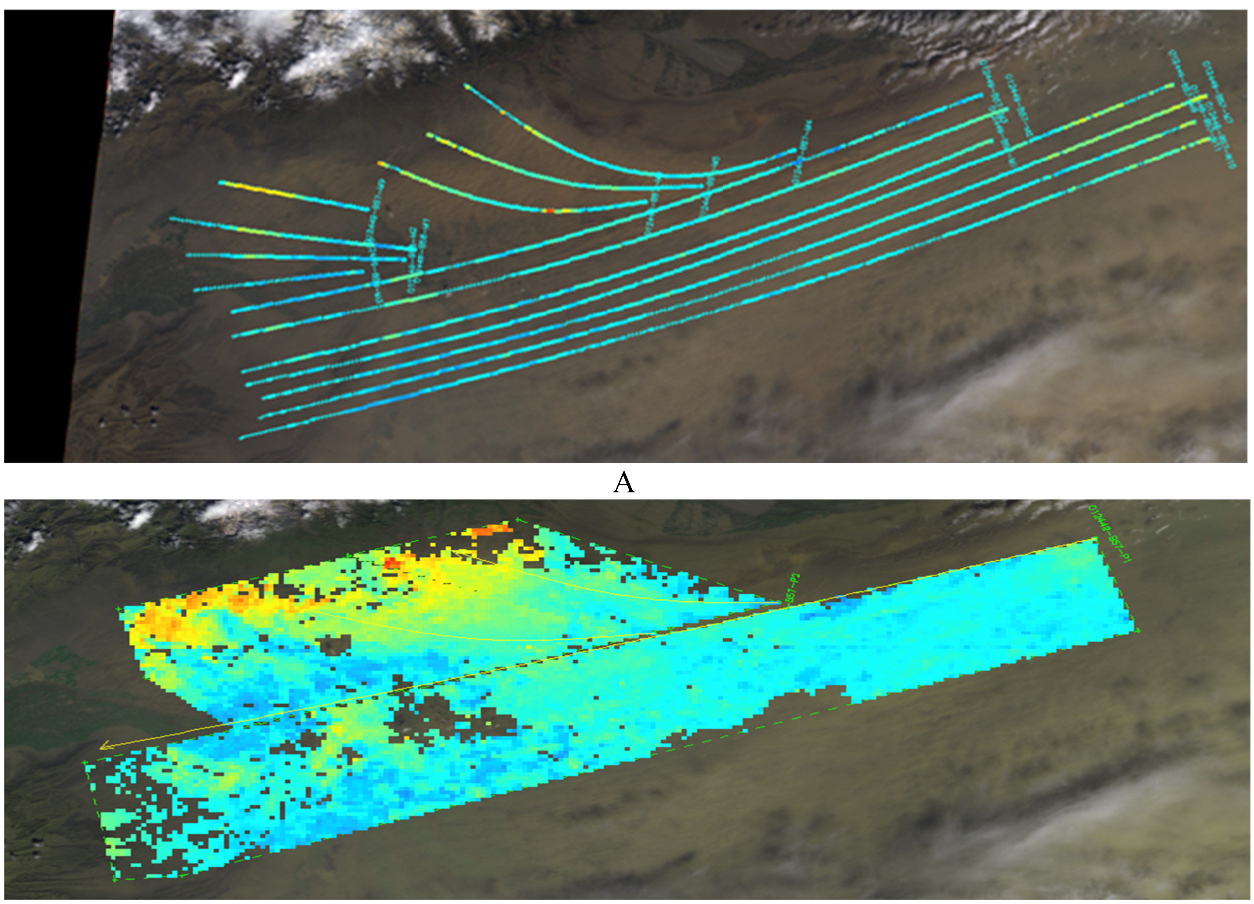
To load the files within MINX[3] the user should select LOAD and input the correct file path. The block range[4] that contains dust also needs to be specified. This allows MINX[3] to only load those files within the specified block range[4]. It is similar to only looking at one portion of interest on a gigantic picture. Once completed, MINX will display the correct region of interest that corresponds to the user's input.

E.4: Pre-Digitization

When a specific file is loaded, one will notice all nine camera images cycling through creating the flipbook effect mentioned earlier. As the cameras cycle through, the effects of parallax[5] between the nine cameras is apparent. Individual features from camera to camera are suppose to match up but do not. To fix this, one needs to warp the image for misregistration. Warping the cameras match up the pixel shifts created by parallax. With warping, a seamless transition between camera images is established.

E.5: Digitization of Dust Plumes

Two different methods are used to analyze dust plumes. These methods are called plume lines and plume polygons. Both methods can be shown in Figure 7.



A

B

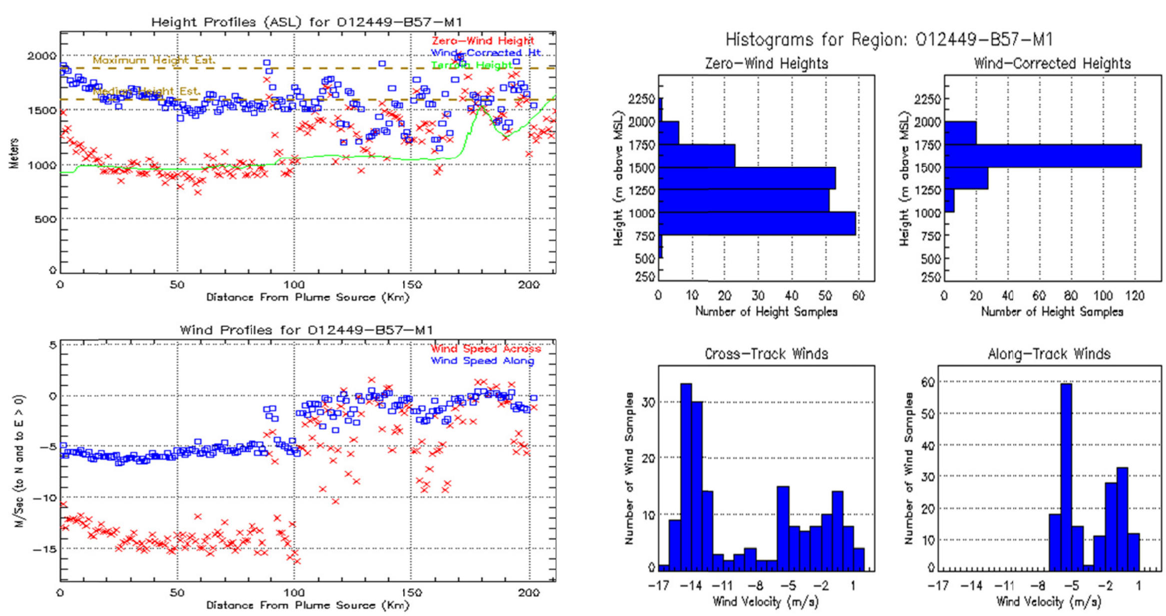
Figure 7: A) Example of plume lines. B) Example of plume polygons

Plume lines are lines created by the user within MINX[3]. These lines are drawn to correspond to the way the wind is blowing. The software uses a complex algorithm and camera matching to retrieve samples along the line that are going the same direction specified. Plume polygons are polygons drawn around the dust instance. All samples within the drawn region are digitized.

Each method has its own advantages and disadvantages. The advantage of plume lines to plume polygons is they are quicker for the software to analyze since the software is only analyzing particles along that line. The disadvantage of plume lines to plume polygons is that they do not give a good representation of a dust plume since it only collects samples along the drawn line. To compensate, one can draw multiple plume lines over the dust instance to get a better representation of the plume.

E.6: Digitization Results

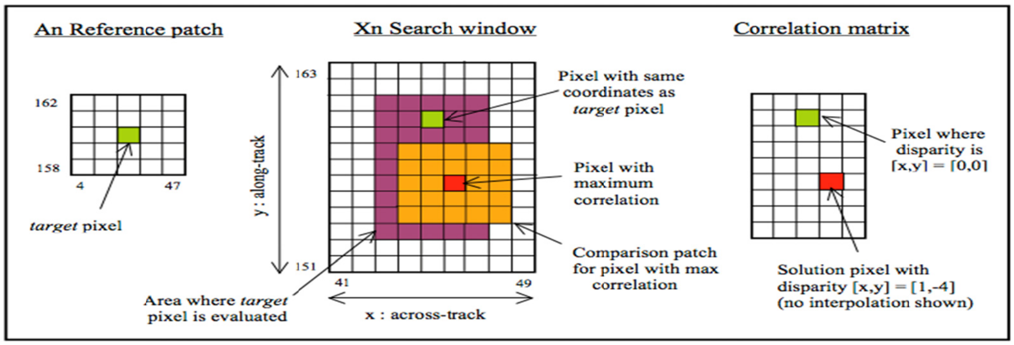
The use of either method produces a series of graphs after digitization. These graphs can be seen in Figure 8.



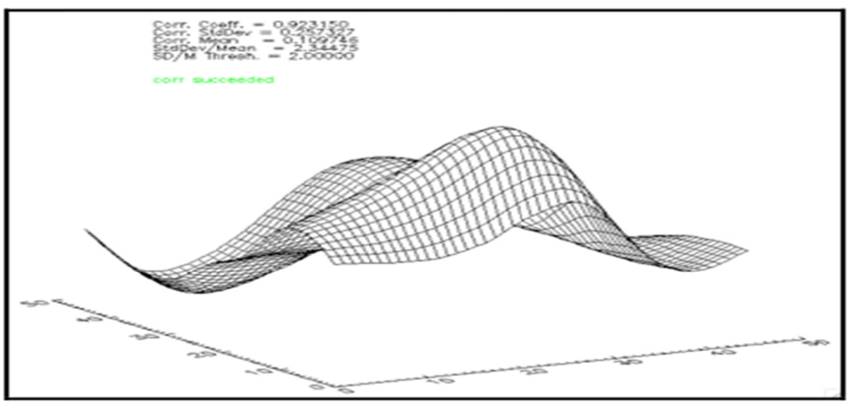
A B

Figure 8: A) Height Plot and Wind Plot generated by MINX. B) Histogram Plot

The first graph is a plume height plot. The terrain is plotted in green and the Zero-Wind Heights and Wind-Corrected Heights are also plotted. Wind-Corrected Heights are the only heights of interest. This is because the Zero-Wind Heights are false heights. These heights are obtained due to the algorithm and camera matching MINX[3] uses. This process is shown in Figure 9.



A



B

Figure 9: A) Camera matching process. The green pixel is the target pixel and the red pixel is the pixel with the highest correlation of a match in relation to the target pixel. B) 3-D rendition of the highest correlation of a match. Nelson, David, Michael Garay, Jeff Hall, and Scholes Matt. "MISR INteractice eXplorer (MINX) V1.2 User's Guide." 2009.

MINX[3] selects a target pixel in the AN camera, which is the camera pointing straight down at the Earth, and compares it to another camera. As it does this, it uses an algorithm to find the highest correlation of a match between the target pixel and another pixel in the other cameras. Once MINX[3] finds the highest correlation of a match, it can be seen in Figure 9 that there is a displacement in the x and y directions. The displacement in the x direction is due to the wind only and the displacement in the y direction is due to wind as well as parallax[5]. The Zero-Wind Heights are generated from this process, but if the user inputs what they feel is the correct wind direction, the software uses that information to give a better representation of the plume heights which is denoted by the Wind-Corrected Heights.

The second plot in Figure 8 is the wind profile of the dust plume. It displays the along track and across track wind direction. To obtain the overall wind speeds just take the resultant of the two velocities. The last plot is a histogram plot that displays the number of samples collected at different heights and wind speeds. Every digitization completed is stored on the servers for climatologist to look at to help them with their climate models.

E.7: Overall Results

The results gathered from digitations within the Taklamakan Desert show dust instances also occurring in the mountain areas that encompass the north and south part of the region. In addition, dust within the region had no consistence wind direction. Figure 10 shows a representation of wind profiles within the Taklamakan Dessert.

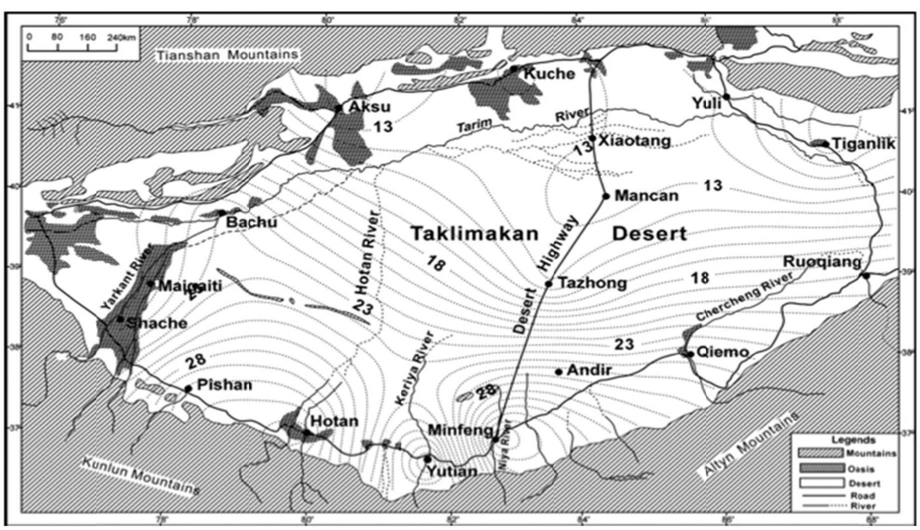


Figure 10: Wind profiles over the Taklamakan Desert. Zu, Ruiping, Xian Xue, Mingrui Qiang, Yang Bao, and Janjun Qu. "Characteristics of near-surface wind regimes in the Taklimakan Desert, China." Science Direct. (2008): 39-47

This figure demonstrates that wind within the region is blowing in different directions and in turn the dust is being transported around the region. This is unique because other dust regions have a consistent wind direction within their region. For example, the Sahara Desert has wind blowing dust out of Africa and over the Atlantic Ocean into North and South America.

Another result is that dust instances within the region occur year round rather than during the spring time as some believed it to be. Figure 11 shows a plot of the number of instances for three years, 2001-2003, at different months. This figure shows that there is peak dust activity in the spring time but another spike in activity occurs during the late summer months.

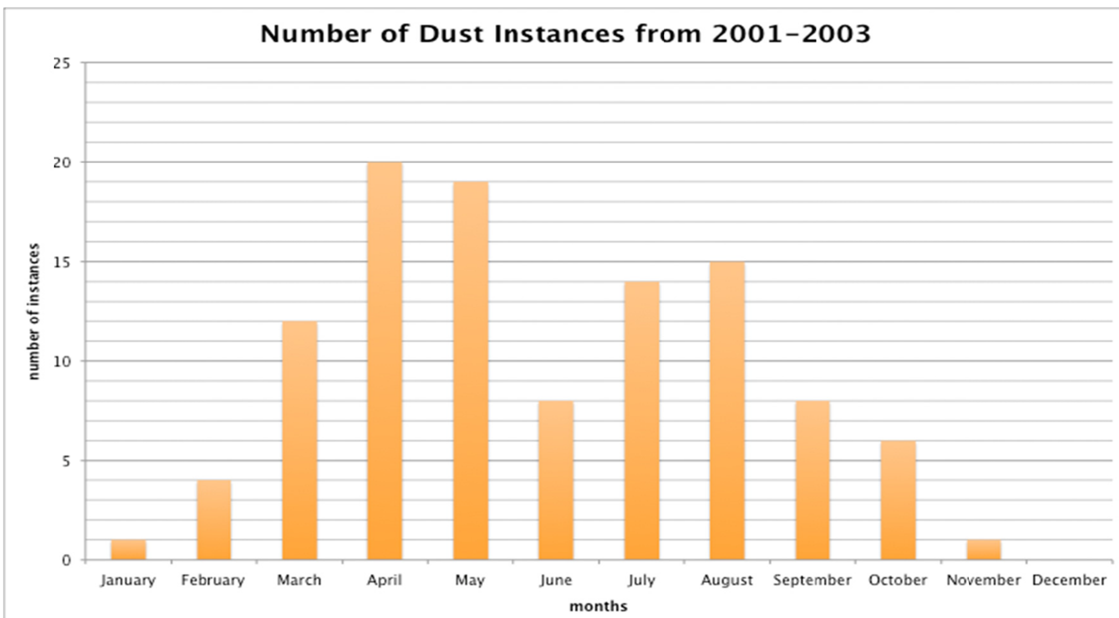


Figure 11: The number of instances during 2001-2003.

F. Suggestions for Further Work, New Objectives, and Action Required

Future work consists of a continuation of analyzing dust instances within Asia but with emphasis on the Gobi Desert. It is known that dust occurs only in the spring time within the Gobi Desert and transportation of dust over the Pacific Ocean is likely caused from this region. Analyzing this region will give an idea of the behavior of dust and its path for transportation. In addition, a comparison between the two regions will be beneficial to the scientific community. This can be accomplished the same way the Taklamakan Desert was analyzed.

G. Personal Comments

This experience has been a wonderful one. Even though my major is Aerospace Engineering, I was greatly thrilled to try something new. One cannot be afraid to step outside the box and discover new possibilities. I have learned a lot from such amazing people I work with; nevertheless, the independence and work experience I obtained is priceless and hard to get without participating in some form of an internship at a company.

H. References

Web: "Aerosol and Cloud Science: People." *JPL Science*. Jet Propulsion Laboratory, n.d. Web. 10 Feb 2011. <http://science.jpl.nasa.gov/people/Kalashnikova/>.

Web: "Early History." *JPL History*. Jet Propulsion Laboratory, n.d. Web. 10 Feb 2011. <http://www.jpl.nasa.gov/jplhistory/early/index.php>.

Book: Nelson, David, Michael Garay, Jeff Hall, and Scholes Matt. "MISR INteractice eXplorer (MINX) V1.2 User's Guide." 2009.

Journal Article: Zu, Ruiping, Xian Xue, Mingrui Qiang, Yang Bao, and Janjun Qu. "Characteristics of near-surface wind regimes in the Taklimakan Desert, China." Science Direct. (2008): 39-47

I. Glossary

[1] Multi-angle Imaging SpectroRadiometer (MISR)-one of five scientific instruments on the Terra satellite.

[2] Path Number-MISR slices the Earth into 233 individual paths. Each path corresponds to a different location on the Earth.

[3] MISR INteractive eXplorer (MINX)-software developed to analyze aerosols.

[4] Block Range-Each orbit is cut into 180 blocks. Block 1 starts at the top of the orbit at the north pole and path 180 concludes the orbit at the bottom of the earth (south pole).

[5] Parallax-the difference or apparent displacement of an object due to viewing that object at different locations relative to that object.